Distributed Energy Resources for Carbon Emissions Mitigation

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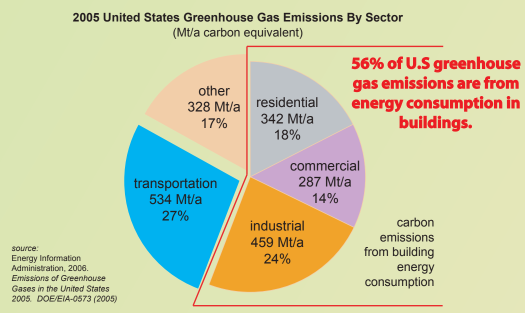
Introduction

U.S. Greenhouse Gas Footprint Footprint



Distributed Energy Resources For Improved Carbon Efficiency

Distributed Energy Resources (DER) are a range of energy conversion and storage technologies including small-scale power generation, thermal and electrical storage, and thermally activated cooling. These technologies can reduce the carbon-intensity of meeting end-use energy loads. Technologies include:

Combined heat and power (CHP): on-site electricity generation (natural gas engines or fuel cells) with waste heat recovery for site heating needs. 60-85% of primary fuel energy can be utilized.

Thermally activated cooling: Absorption and adsorption chillers use heat, rather than electricity, to provide cooling.

Solar technologies: Photovoltaics provide renewable electricity. Solar thermal collectors can be used to provide heat for domestic hot water and/or thermally activated cooling. High temperature collectors can provide steam for industrial processes.

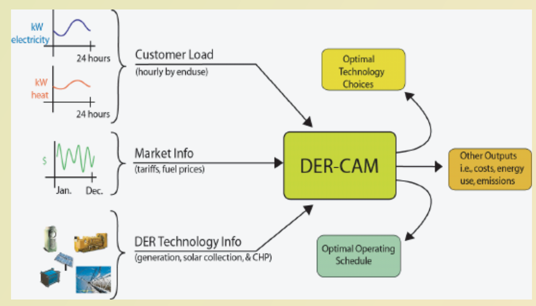
Storage: Storage devices such as batteries and thermal tanks can be used to improve reliability and to apply energy produced or purchased during a low value time to loads at a higher value time.

The Distributed Energy Resources Customer Adoption Model

The Distributed Energy Resources Customer Adoption Model (DER-CAM) is a site-specific, fully technology neutral DER investment and operation optimization tool developed by the DER team at the Berkeley Lab.

Inputs include
-site hourly electricity and heating load profiles
-energy prices
-DER investment options
-operational constraints such as limits on carbon emissions

Outputs include
-optimal DER investment
-optimal operating schedule
-performance measures such as annual energy cost, electricity and natural gas consumption, and carbon emissions attributed to energy consumption



Experiment: What are the economically optimal DER technologies for U.S commercial buildings *under a carbon tax*?

DER-CAM was used to determine the economically optimal DER investment for prototypical commercial buildings in several U.S. cities under a range of carbon tax levels.

Building energy simulations were conducted to determine electricity, natural gas, space and water heating, and cooling loads for each building type in each location. City-specific weather, energy costs, and electric grid carbon-intensity values were used.

Building Types:
- health care (small and large)
- lodging (small and large)
- office (small and large)

Cities:
- Atlanta, Georgia
- Boston, Massachusetts
- San Francisco, California

Results: Technology Adoption, Costs, and Carbon Emissions

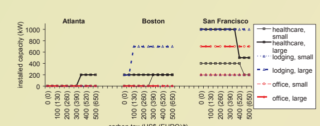


Figure 1: installed capacity of CHP generators

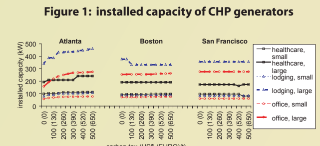


Figure 2: installed capacity of absorption chillers

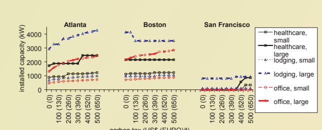


Figure 3: installed capacity of solar therm collectors

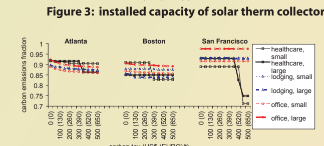


Figure 4: site-attributable carbon emissions as a fraction of no-invest carbon emissions

note: Thermal storage was never purchased. Electrical storage and photovoltaics were only purchased in a handful of cases.

Conclusions

Atlanta
- Electricity prices are too low to incent CHP.
- Integrated solar thermal/absorption chiller systems are economic even without a carbon tax.
- Solar collector/absorption chiller system size increases with carbon tax.
- A realistic carbon tax of \$100/tC incents less than one percent carbon reductions.

Boston
- CHP is marginally economic without the carbon tax and is increasingly adopted with carbon tax.
- Solar thermal/absorption chiller systems are economic.
- A realistic carbon tax level (\$100/tC) incents less than one percent carbon reduction.

San Francisco
- All buildings considered would benefit financially from CHP, even without carbon taxes.
- Carbon emissions reductions from DER investment are less than in Atlanta and Boston.
- The relatively low electric grid marginal carbon emissions and high electricity prices in California induce some carbon-inefficient behavior, such as operating CHP when the heat is not needed.
- Carbon taxes have little effect on investment behavior and almost none on carbon emissions.

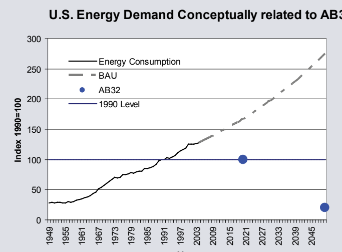
Overall
A realistic carbon tax (\$100/tC) is too small to incent significant carbon-reducing effects on economically optimal DER adoption.
- Cost reduction and carbon reduction objectives are roughly aligned, even in the absence of a carbon tax.
- A carbon tax greater than \$500/tC would be required to incent significant adoption of carbon-free renewable energy.

Acknowledgments: The work described in this report was funded by the Office of Electricity Delivery and Energy Reliability, Distribution System Integration Program of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231, and by the California Energy Commission, Public Interest Energy Research Program, under Work for Others Contract No. 500-03-024. The poster also builds on prior work the authors have completed together with Giri Venkataramanan, University of Wisconsin, Madison, Afzal S Siddiqui, University College, London, Michael Stadler, Center for Energy and innovative Technologies, Ypsertal, Austria, Bala Chandran, Kristina Hamachi LaCommare, Judy Lai, and Nan Zhou, Berkeley Lab, and Owen Bailey, Cornell University.

Modeling California's Potential for Energy and Carbon Reductions in Commercial Buildings

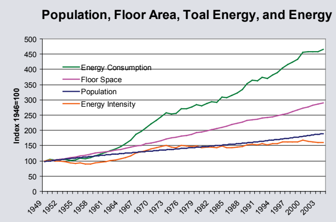
Sam Borgeson and Brian Coffey, Lawrence Berkeley National Laboratory

Energy Targets and Goals



The goal of this modeling study is to explore the magnitudes of changes needed in new and existing commercial buildings to bring that sector into alignment with the AB32 goals. AB32 sets a binding economy wide target for returning to 1990 levels of emissions by 2020 and a long term goal of reducing emissions to 20% of 1990 levels by 2050. For the purpose of our work, we have assumed that the commercial building sector should track the AB32 goals and that onsite energy generation and fuel switching should be the last elements factored in to the analysis.

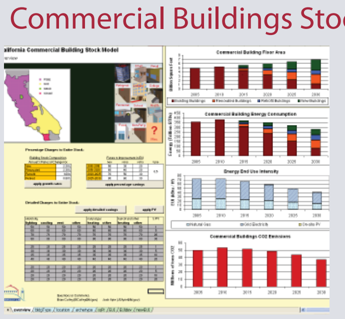
Key Characteristics and Parameters



Total Energy consumption can be thought of as a function of energy intensity per unit of floor space and floor space can be though of as a function of population size. Here we see that total national floor space is growing faster than population, indicating that we are steadily increasing our per-capita building space requirements.

Note that this data is national, and therefore does not reflect CA specific trends and behaviors.

Commercial Buildings Stock Model

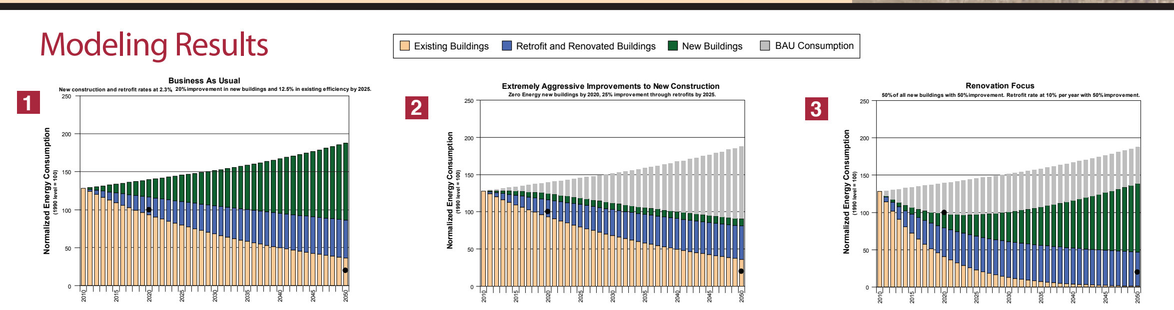


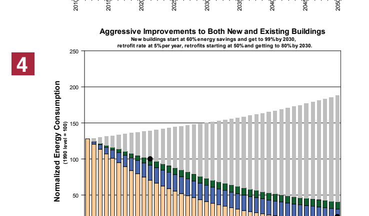
Assumptions:
- Constant annual growth rate in floor space Default value of 2.3% from EIA data
- Constant annual rates of retrofit and renovation
- Effects of code improvements roughly able to offset additional plug loads (both ignored)

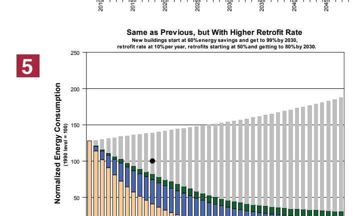
Model parameters:
- Floor space growth rate
- Retrofit and renovation rates
- EUI (Energy Use Intensity in kWh/sqft/yr) improvement levels from retrofits and renovation
- New construction EUI evolution over time
- Penetration of onsite solar generation

Model Versions and Data:
- Qualitative behavior can be derived from purely hypothetical floor space and EUI numbers
- U.S. model built using CBECS data, including floorspace and EUI broken out by building type, and region
- CA model built using CEUS data, including floorspace and EUI broken out by building type, and region
- Analytica model built to examine sensitivity and introduce uncertainty

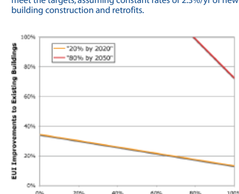
Modeling Results



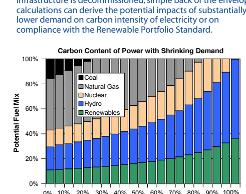




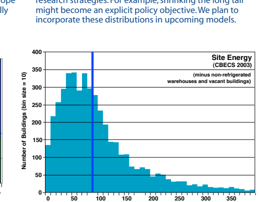
Working backwards from the AB32 targets, it is possible to determine the range of parameters from this model that can deliver them. Below is a simple example, showing the Range of energy savings values in new and existing buildings that meet the targets, assuming constant rates of 2.3%/yr of new building construction and retrofits.



Buildings use 70% of electricity. In California, 40% of electricity comes from nuclear, large hydro or renewables. Assuming that demand reductions from buildings can be used to decommission dirty energy supplies and no other generation infrastructure is decommissioned, simple back of the envelope calculations can derive the potential impacts of substantially lower demand on carbon intensity of electricity or on compliance with the Renewable Portfolio Standard.



The figure below shows the distribution of energy use intensities for buildings in the CBECS data set. Analyses of these distributions for various regions and building types is important in the development of policy and research strategies. For example, shrinking the long tail might become an explicit policy objective. We plan to incorporate these distributions in upcoming models.



About the Zero-Energy Commercial Buildings Initiative

Vision: By 2030, commercial buildings in the United States will be carbon-neutral, having integrated aggressive energy efficiency measures to dramatically reduce demand by 80 percent and meeting the remaining energy requirements through renewable energy resources.

Approach: We propose a coordinated, multi-year national strategy for public-private collaboration that integrates: deployment, demonstration, and innovation to achieve the vision for "zero energy" commercial buildings.

Partners: Alliance to Save Energy, American Institute of Architects, American Society of Heating Refrigerating and Air-conditioning Engineers, Lawrence Berkeley National Laboratory, US Green Building Council, World Business Council for Sustainable Development, and more to be added soon.

Conclusions

2020 vs. 2050

Buildings last for 40 years or more. Consequently, we can expect large portions of the total building stock today to still be in service in 2020 and some well past 2050. Hitting the 2020 target will therefore be mostly a matter of updating existing buildings. At timescales out to 2050, however, updates are not enough. Energy savings become largely dependent on innovation in new buildings. Therefore, separate, but complimentary strategies focused on retrofits, plug loads, and the development of new building technologies will be required to hit both targets.

Retrofits and Renovation

Retrofits, as measured by affected square footage and delivered performance, have a leading role to play in efforts to dramatically reduce greenhouse gas emissions associated with buildings. Since retrofit technologies and costs are often different from those associated with new buildings, they will require their own dedicated research.

Growth in Per-capita Square Footage

Total square footage in buildings is growing faster than the population of people using them and is having a very large impact on total energy consumption. This trend is invisible to analysis that measures building energy performance is in energy per square foot, i.e. Title 24's performance option.

Renewable Energy

As a starting point, we might generously assume that building efficiency measures alone could produce energy savings of 50-75% per building. However, any savings beyond that limit, whatever it is, will require onsite renewable generation or onsite combustion of carbon neutral fuels.

Carbon Content

As the total building stock becomes more efficient, there exists the possibility that electricity demand would be lowered sufficiently to allow the decommissioning of dirty supplies of power. Through this mechanism, we could expect building energy savings to result in lower carbon content electricity without the addition of any new renewable energy capacity.

Plug Loads

The energy use intensity of buildings (e.g. kWh/sqft/yr) has been steadily increasing for decades. This is largely due to the fact that the number of electronic devices in a typical commercial space has steadily grown. Much of the potential for "building energy" savings comes in the form of device efficiency, controls, and replacement, not changes to the core and shell.

Equipment Turnover

The machinery that runs a building turns over faster than the building itself. From light bulbs to windows to chillers, the consistent adoption of the most efficient equipment available at modest additional cost as older equipment wears out could substantially lower building energy use by 2020 and beyond at little or no cost to consumers.